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1984/85 ST. CROIX RIVER WATER QUALITY REPORT

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1984/85 ST. CROIX RIVER

WATER QUALITY REPORT

IWD-AR-WQB-85-89

Inland Waters Directorate

Environment Canada

Geoffery Howell

Water Quality Branch

Atlantic Region

Moncton, New Brunswick

August 29, 1985

A copy will be made available in French upon request

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LETTER OF TRANSMITTAL

Water Quality Branch
Inland Waters Directorate
Environment Canada
P. O. Box 861
Moncton, N. B.
August 29, 1985

Chairman, Canadian Section
IJC Pollution Advisory Board

Re: St. Croix River Water Quality Report 1983-84

This is the fifth annual report of the Water Quality of the St. Croix River, prepared by the Water Quality Branch.

The report concentrates on the Kellyland-Milltown portion of the river and incorporates data gathered from three stations at approximately six week intervals. In addition, data from the USGS Automatic Water Quality Monitor for the period May 8, 1985 to August 18, 1985 are presented.

Observations and comments on this report would be welcome.

Yours sincerely,

D. H. Cullen, Chief
Water Quality Branch

ABSTRACT

This report presents the results of the 1984-85 St. Croix River water quality monitoring program. Physical parameter, major ion, heavy metal and nutrient concentrations are presented for three stations sampled on seven dates. Data from the Milltown Automatic Water Quality Monitor (AWQM) are presented for the period May 8, 1985 to August 18, 1985. These data are discussed briefly and are used to construct an AWQM specific nomogram which can predict dissolved oxygen saturation from water temperature and specific conductance.

RÉSUMÉ

Ce rapport présente les résultats du programme de monitorage de la qualité des eaux de la rivière Ste-Croix pour 1984-1985. Les concentrations en ions majeurs, paramètres physiques, éléments nutritifs et métaux lourds sont présentées pour chacunes des trois stations, échantillonnées en sept occasions. Les données provenant du moniteur automatique de la qualité des eaux à Milltown sont présentées pour la période du 8 mai 1985 au 18 août 1985. Ces données sont discutées brièvement et sont utilisées pour construire un nomogramme spécifique au moniteur automatique de la qualité des eaux. Ce nomogramme peut prédire la saturation en oxygène dissous à partir de la température de l'eau et de la conductivité spécifique.

INTRODUCTION

The Water Quality Branch conducts regular water quality sampling in the International portion of the St. Croix River to monitor the concentrations of toxic substances and other chemicals in the river water. These activities assist the Advisory Board on Pollution Control in the St. Croix River in fulfilling its mandate of co-ordinating water quality planning and management efforts in the basin. In addition, the Water Quality Branch has established a satellite retransmission system for the USGS Automatic Water Quality Monitor Data and also participate in the development of water quality objectives with particular reference to the passage of Atlantic Salmon (Salmo Salar).

This report presents the water quality data from three stations sampled on seven occasions during the period May 1984 to May 1985. In addition the AWQM data for the period of May 1985 to August 1985 is also presented. As the water quality conditions of the St. Croix River have been discussed at length in previous reports (MS Report 1980; MS Report 1981, Howell and Lockerbie, 1983), this report serves to present the current year's data along with a brief characterization of water quality conditions at three stations.

THE STUDY AREA

The study area is that part of the river which forms the international boundary between United States and Canada and represents a reach of approximately 124 km. In most of the drainage area and for the upper 110 km, the St. Croix River is considered to be pristine. It is the 14 km stretch between Woodland, Me. and Milltown, New Brunswick which is considered to be a water quality limited segment, even though it is now capable of supporting an anadramous run of Atlantic Salmon (Salmo salar). The problem in this reach is caused by a major industrial discharge from the Georgia-Pacific Kraft Pulp Mill at Woodland and to a lesser extent by municipal discharge and combined sewage outflows from the communities of Woodland and Baileyville, Me.

METHODS

The Water Quality Branch of Environment Canada sampled the St. Croix River on seven occasions during the 1984-1985 study period at three stations located at Kellyland, Woodland, and Milltown (Figure 1). The Kellyland station is considered to be pristine and thus is indicative of background water quality conditions. The Woodland site is located near to the Georgia-Pacific Pulp Mill effluent outfall and serves to characterize the chemical composition of the effluent after slight dilution by river water. The Milltown station, 14 km below Woodland, provides information on the rate and extent of pulp mill effluent, assimilation and dilution by the river. Descriptions and NAQUADAT numbers of the three water quality stations are presented in Table 1.

The Water Quality Branch sampling was conducted as outlined in the "Sampling for Water Quality" Manual (WQB, 1983) and the analytical methods employed are described in the NAQUADAT Dictionary (WQB, 1983). A list of the selected water quality parameters, their NAQUADAT codes and detection limits are presented in Table 2. Water Quality Branch, Atlantic Region Quality Control procedures require that 15% of the samples must be collected in triplicate and that preservative blanks must be prepared for each sampling occasion. The results of these QA/QC procedures are not discussed but the data are presented in the appropriate tables. Data from the AWQM at Milltown was obtained by using a Labarge GOES satellite retransmission platform.

RESULTS AND DISCUSSION

Kellyland - 00NB01AR0013

Physical measurements, major ions, heavy metal and nutrient concentrations for seven sampling dates are presented in Tables 3 to 6 respectively.

The station at Kellyland is located 15 km upstream of Woodland and is indicative of background water quality conditions. Water temperature at Kellyland ranged from 1.1°C to 21.0°C, apparently following ambient air temperature. Dissolved oxygen concentrations were high on all occasions ranging from 8.6 mg/L in August to 13.5 mg/L in December. Oxygen saturations ranged from 86% to 95% which is characteristic of waters with water colours ranging from 10 up to 45 Hazen Units.

The waters of the St. Croix River at Kellyland are dilute, having specific conductivities ranging from 26 uS/cm to 40 uS/cm. The dominant cation is calcium (0.150 to 0.215 meq/L) while magnesium (.044 - .072 mg/L) and sodium (.044 - .074 meq/L) are found in nearly equal proportions and share the position of the second most abundant cation. The anions are dominated by bicarbonate (.110 - .168 meq/L), followed by sulphate (.052 - .104 meq/L) and chloride (.028 - .059 meq/L).

Concentrations of copper, lead, mercury and cadmium were without exception below or near to the level of detection. Iron and manganese concentrations were relatively constant, having ranges of 0.06 - 0.16 mg/L and 0.01 - 0.03 mg/L respectively. Aluminum concentrations ranged

from 0.018 mg/L to 0.078 mg/L.

Woodland - 00NB01AR0014

The Woodland water quality station is situated on the United States side of the river, approximately 200 meters below the point of Woodland Mill effluent discharge. At this location, morphometry of the river prevents complete mixing of the effluent with river water and thus provides an indication of the chemistry of pulp mill effluent. Tables 3 to 6 present the physical parameter, major ion, heavy metal and nutrient data respectively.

The temperature of the St. Croix River at Woodland is highly dependent on effluent temperature and thus remains high throughout the entire year (18.5 to 27.0^{o}C). Water colour is extremely high and variable (1000 - 1600 Hazen Units) due to elevated concentrations of dissolved organic matter and black liquor in the treated pulp mill effluent. Specific conductance at Woodland exceeds that observed at Kellyland by a factor of approximately 60. This is reflected in the major ion concentrations which are 1 to 3 orders of magnitude greater than at Kellyland. Unlike Kellyland, major ion chemistry is dominated by sodium and chloride ions, as a result of their extensive use in the Kraft process.

Mercury concentrations were always below the detection limit while values near to the detection limit were observed for cadmium, lead and copper. Iron concentrations were slightly elevated (0.59 to 0.93 mg/L) while manganese values were approximately two orders of magnitude

greater than observed at the background station. Extractable aluminum values are elevated (1.7 to 2.8 mg/L) which is probably a consequence of the use of alum in the pulp mill treatment facility.

As would be expected, the high load of organic matter results in elevated concentrations of nutrients and organic carbon. Dissolved organic carbon concentrations are extremely high and variable ranging from 11 to 210 mg/L. Total nitrogen values range from 0.5 to 6.0 mg/L and are characteristic of hypereutrophic conditions (Likens, 1975). Although much of this nitrogen is likely to be combined with organic matter, the high nitrate concentrations indicates that some of the nitrogen is in available form. The fact that there is little evidence of elevated planktonic or macrophytic primary production would suggest that other nutrients such as phosphorus are limiting the system.

Milltown - 00NB01AR0001

At Milltown, 14 km downstream from Woodland, water temperatures are similar to those observed at the background station having a range of 0.5 to 21.0^{o}C. The effects of effluent loading are reflected in elevated water colours (55 to 120 Hazen Units) and an occasional depression in dissolved oxygen concentration relative to the background station. The highly organic nature of the pulp mill effluent results in an oxygen demand which in the past has resulted in reduced summer oxygen concentrations at Milltown (Howell & Lockerbie, 1983b; Howell 1984). In an attempt to re-establish Atlantic Salmon in the St. Croix River a dissolved oxygen objective of 60% saturation or 5 mg/L has been set. On all occasions the 1984/85 grab sampling dissolved oxygen concentrations

and saturations were well above the water quality objective. Dissolved oxygen concentrations ranged from 7.5 to 13.0 mg/L in response to varying water temperature. Dissolved oxygen saturations ranged from 80 to 96% with the lowest values corresponding to periods of high water colour and specific conductance.

Major ion chemistry at Milltown reflects a mixture of the background calcium bicarbonate dominated waters of the St. Croix River and the sodium chloride dominated pulp mill effluent. Specific conductance values are highly variable, ranging from 45 uS/cm to 157 uS/cm. The dominant cation is generally sodium, but is followed closely by calcium when the specific conductance is low. Bicarbonate and chloride alternate as the dominant anion, with bicarbonate being dominant during low specific conductance periods and chloride being dominant when the conductance is high.

Concentrations of copper, lead, cadmium and mercury at Milltown were below detection on all occasions. As would be expected concentrations of aluminum, iron and manganese were slighly elevated above background conditions, presumably as a result of high levels observed in the pulp mill effluent. Nutrient concentrations were without exception slightly elevated above the values observed at Kellyland.

Milltown - AWQM Data

Appendix 1 (under separate cover) presents the hourly Milltown AWQM data for the period May 8/1985 to August 19/1985. In addition to measurements of water temperature, pH, specific conductance and

dissolved oxygen, calculated oxygen saturation values are also presented.

Water temperature ranged from a low of 9.0°C on May 8 to a maximum of 26.5°C on August 16. Water temperatures increased steadily during May but levelled off during June in response to mild rainy weather (Figure 2). The onset of warmer weather in late June and early July resulted in approximately a 5°C increase in water temperature reaching a plateau at about 24°C.

The seasonal distribution of AWQM pH data is presented in Figure 3 and with the exception of some spurious instantaneous readings, ranges from 5.6 to 7.6. Values of pH were relatively stable (7.2 - 7.5) from May 8 up to July 17, but dropped rapidly to the 6.5 range from July 18 to August 8. These depressed pH levels follow a period of low flow rate and high effluent loading and thus may be the result of increased heterotrophic activity.

The seasonal distribution of dissolved oxygen concentrations and saturations are presented in Figures 4 and 5 respectively. As would be expected dissolved oxygen concentrations decreased during May and June, in response to increasing water temperature. However the sudden decrease in dissolved oxygen between Julian days 185 to 195 (July 4 - July 14) does not correspond with a rapid increase in water temperature. Instead, these reductions are the result of increased system oxygen demand, due to high effluent discharge during low flow conditions. Dissolved oxygen concentrations during this period were very close to the 5.0 mg/L dissolved oxygen objective and on two occasions were non-compliant.

This situation was remedied by an increased river discharge rate at the Woodland Dam. By considering percent saturation of dissolved oxygen rather than concentration, it is possible to remove the effects of water temperature on solubility. Figure 5 indicates a slight reduction in dissolved oxygen saturation during the period May 8 to July 4 due to the biochemical oxygen demand of the system. This oxygen demand becomes critical during low flow conditions in July, resulting in a rapid reduction in dissolved oxygen saturation. In fact for a period of eight days many of the instantaneous dissolved oxygen saturations were slightly below the 60% water quality objective.

Values of specific conductance (Figure 6) for the monitoring period are highly variable as a consequence of variable river and effluent discharge rates. Overall, specific conductance increased during May and June, reaching a peak (180 uS/cm) during the period of low dissolved oxygen saturation in July. After this peak period, increased river discharge resulted in a slight decrease of Milltown specific conductance.

Dissolved Oxygen Nomogram

Previous reports on the St. Croix River (Howell and Lockerbie, 1983, Howell 1984) have noted that there is a good relationship between specific conductance and dissolved oxygen saturation at Milltown. Howell (1984) presented a nomogram derived from 5 years of grab sampling data, which predicted dissolved oxygen saturation from specific conductance and water temperature. It was noted that although this nomogram predicts well using grab data, there may be a significant

prediction error when considering AWQM data. Figure 7 presents the observed AWQM dissolved oxygen saturation data versus the predicted values and indicates that the nomogram predicts AWQM data poorly. On the other hand, the grab sampling data exhibits better agreement with the nomogram predicted values.

To overcome this problem, a linear multiple regression of dissolved oxygen saturation versus water temperature and specific conductance was attempted using the AWQM data. The results of this regression analysis are presented in Table 7 and indicate that 79% of the variations in dissolved oxygen saturation can be explained by variations in water temperature and specific conductance. Using this regression analysis a new AWQM derived nomogram was constructed and is presented in Figure 8. Table 8 presents statistics on the difference between observed and predicted dissolved oxygen saturation for 128 measurements. These data indicate that the nomogram predicts values close to those actually measured by the AWQM. Therefore, it is proposed that this nomogram can be employed to predict dissolved oxygen saturation at Milltown during periods when the AWQM oxygen system is inoperable and may also be used to flag possible AWQM calibration problems.

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TABLE 1: NAQUADAT Numbers and Site Descriptions of the Selected Sampling Stations on the St. Croix River

NAQUADAT Numbers	Site Description
00NB01AR0013	Saint Croix River at Kellyland
00NB01AR0014	Saint Croix River, 200 m below Woodland Mill on the U.S. side of the river
00NB01AR0001	Saint Croix River at Milltown Hwy Bridge - Mid-river

TABLE 2: A list of parameters, parameter codes and their detection limits

Parameter	NAQUADAT Parameter Code	Detection Limits
Temperature	02065S	-
Dissolved Oxygen (meter)	08102F	-
Dissolved Oxygen (Winkler)	08101F	10 ug/L
Specific Conductance	02042F	2 uS/cm
pH	10301F	-
Specific Conductance	02041L	0.2 uS/cm
pH	10301L	-
Colour	02011L	-
Turbidity	02073L	0.0
Extractable Iron	26304P	50. ug/L
Extractable Manganese	25304P	10. ug/L
Extractable Copper	29305P	0.1 ug/L
Extractable Lead	82303P	1. ug/L
Extractable Aluminum	13305P	2. ug/L
Extractable Mercury	80315P	.02 ug/L

Extractable Cadmium	48302P	1. ug/L
Sodium	11103L	0.1 mg/L
Calcium	20110L	.04 mg/L
Potassium	19103L	0.1 mg/L
Magnesium	12107L	.005 mg/L
Chloride	17201L	0.1 mg/L
Sulfate	16304L	1.0 mg/L
Total Alkalinity	10101L	0.5 mg/L

TABLE 3: MEASUREMENTS OF TEMPERATURE, DISSOLVED OXYGEN, SPECIFIC CONDUCTANCE, PH, WATER COLOUR AND TOTAL ALKALINITY FOR THREE ST. CROIX RIVER STATIONS

0 STATION	1 SAMPLE DATE	2 SAMPLE TIME	3 WATER TEMP. DEG C	4 DISSOLVED OXYGEN MG/L	5 FIELD SP. COND. US/CM	6 LABORATORY SP. COND. US/CM	7 FIELD PH	8 LAB PH	9 TOTAL ALKALINITY MG/L	10 WATER COLOUR H U
00NB01AR0001	14-MAY-84	1630	12.4	10.3	46	45		6.5	6.7	55
00NB01AR0001	25-JUN-84	1710	18.5	9.2	63	59		6.8	9.2	65
00NB01AR0001	01-AUG-84	1030	21.0	7.5		53	6.9	6.9	10.3	60
00NB01AR0001	01-AUG-84	1045	21.0	7.5		52		7.0	9.7	60
00NB01AR0001	01-AUG-84	1100	21.0	7.5		52		7.0	9.8	60
00NB01AR0001	23-OCT-84	1415	12.8	8.6		136	6.8	7.0	23.4	120
00NB01AR0001	19-DEC-84	1445	1.3	13.0	111	114		7.0	15.2	70
00NB01AR0001	18-FEB-85	1415	0.5	11.9	138	157		6.6	20.1	80
00NB01AR0001	18-FEB-85	1416	0.5	11.9	138	156		6.7	21.4	80
00NB01AR0001	18-FEB-85	1435	0.5	11.9	138	156		6.7	20.4	80
00NB01AR0001	17-MAY-85	1300	13.0	9.0	112	105	7.0	6.9	13.9	80
00NB01AR0013	14-MAY-84	1530	12.0	10.4	16	27		6.5	5.7	45
00NB01AR0013	14-MAY-84	1535	12.0	10.4		27		6.5	5.7	40
00NB01AR0013	14-MAY-84	1540	12.0	10.4		27		6.5	5.5	35
00NB01AR0013	25-JUN-84	1615	18.7	8.7	16	26		6.6	5.8	25
00NB01AR0013	01-AUG-84	805	21.0	8.6		27	7.0	6.9	6.1	35
00NB01AR0013	23-OCT-84	1215	11.2	10.5		28	6.8	6.8	6.4	20
00NB01AR0013	23-OCT-84	1245	11.2	10.5		28		6.7	6.3	20
00NB01AR0013	23-OCT-84	1230	11.2	10.5		28		6.8	6.5	20
00NB01AR0013	19-DEC-84	1201	1.1	13.5	32	38		6.7	7.1	40
00NB01AR0013	18-FEB-85	1230	1.2	12.3	35	40		6.6	8.4	10
00NB01AR0013	17-MAY-85	1125	12.5	10.0	30	36		6.7	7.5	35
00NB01AR0013	17-MAY-85	1130	12.5	10.0	30	36		6.8	7.8	35
00NB01AR0013	17-MAY-85	1135	12.5	10.0	30	36		6.8	7.8	35
00NB01AR0014	14-MAY-84	1710	19.0	9.1	1900	2000		7.3	269.0	1200
00NB01AR0014	25-JUN-84	1850	26.0	7.8	1880	1810		7.2	215.0	1000
00NB01AR0014	01-AUG-84	920	27.0			1510	7.7	7.4	266.0	1400
00NB01AR0014	23-OCT-84	1330	26.0	6.1		2270	7.8			1600
00NB01AR0014	19-DEC-84	1330	20.7		2200	2450		7.6	330.0	1400
00NB01AR0014	19-DEC-84	1335	20.7		2200	2450		7.7	324.0	1400
00NB01AR0014	19-DEC-84	1340	20.7		2200	2460				1400
00NB01AR0014	18-FEB-85	1330	18.5		1960	2770		7.3		1000

TABLE 4:MAJOR ION EQUIVALENT CONCENTRATIONS FOR
THREE ST. CROIX RIVER STATIONS

0	1 STATION	2 SAMPLE DATE	3 SAMPLE TIME	4 CALCIUM MEQ/L	5 MAGNESIUM MEQ/L	6 POTASSIUM MEQ/L	7 SODIUM MEQ/L	8 CHLORIDE MEQ/L	9 SULPHATE MEQ/L	10 BICARBONATE MEQ/L
	00NB01AR0001	14-MAY-84	1630	0.150	0.048	0.013	0.217	0.135	0.083	0.134
	00NB01AR0001	25-JUN-84	1710	0.185	0.061	0.014	0.248	0.169	0.129	0.184
	00NB01AR0001	01-AUG-84	1030	0.205	0.052	0.013	0.204	0.093	0.119	0.206
	00NB01AR0001	01-AUG-84	1045	0.205	0.052	0.014	0.222	0.093	0.119	0.194
	00NB01AR0001	01-AUG-84	1100	0.205	0.052	0.014	0.217	0.099	0.119	0.196
	00NB01AR0001	23-OCT-84	1415	0.324	0.065	0.032	0.809	0.409	0.223	0.468
	00NB01AR0001	19-DEC-84	1445	0.294	0.080	0.028	0.570	0.375	0.256	0.304
	00NB01AR0001	18-FEB-85	1415	0.324	0.090	0.037	0.913	0.649	0.322	0.402
	00NB01AR0001	18-FEB-85	1416	0.329	0.090	0.037	0.913	0.649	0.312	0.428
	00NB01AR0001	18-FEB-85	1435	0.334	0.090	0.041	0.913	0.649	0.322	0.408
	00NB01AR0001	17-MAY-85	1300	0.264	0.071	0.024	0.583	0.406	0.229	0.278
	00NB01AR0013	14-MAY-84	1530	0.155	0.044	0.010	0.052	0.042	0.062	0.114
	00NB01AR0013	14-MAY-84	1535	0.150	0.048	0.008	0.048	0.042	0.052	0.114
	00NB01AR0013	14-MAY-84	1540	0.150	0.048	0.008	0.048	0.042	0.052	0.110
	00NB01AR0013	25-JUN-84	1615	0.140	0.045	0.059	0.044	0.037	0.067	0.116
	00NB01AR0013	01-AUG-84	805	0.150	0.045	0.008	0.052	0.028	0.067	0.122
	00NB01AR0013	23-OCT-84	1215	0.150	0.044	0.008	0.052	0.028	0.073	0.128
	00NB01AR0013	23-OCT-84	1245	0.155	0.044	0.008	0.052	0.028	0.073	0.126
	00NB01AR0013	23-OCT-84	1230	0.155	0.044	0.008	0.052	0.031	0.069	0.130
	00NB01AR0013	19-DEC-84	1201	0.215	0.072	0.012	0.070	0.059	0.104	0.142
	00NB01AR0013	18-FEB-85	1230	0.215	0.071	0.010	0.074	0.059	0.094	0.168
	00NB01AR0013	17-MAY-85	1125	0.200	0.068	0.009	0.065	0.054	0.083	0.150
	00NB01AR0013	17-MAY-85	1130	0.200	0.071	0.010	0.065	0.054	0.079	0.156
	00NB01AR0013	17-MAY-85	1135	0.200	0.070	0.009	0.065	0.054	0.078	0.156
	00NB01AR0014	14-MAY-84	1710	2.744	0.477	0.051	1.653	10.998	0.936	5.380
	00NB01AR0014	25-JUN-84	1850	2.295	0.362	0.550	13.920	7.614	4.680	4.300
	00NB01AR0014	01-AUG-84	920	3.243	0.321	0.435	12.180	4.794	3.910	5.320
	00NB01AR0014	23-OCT-84	1330	4.241	0.493	0.512	17.400	10.152	3.661	
	00NB01AR0014	19-DEC-84	1330	3.543	0.526	0.589	20.010	12.972	4.368	6.600
	00NB01AR0014	19-DEC-84	1335	3.543	0.526	0.602	20.880	12.690	4.368	6.480
	00NB01AR0014	19-DEC-84	1340	3.593	0.526	0.602	20.010	12.972	4.451	
	00NB01AR0014	18-FEB-85	1330	3.263	0.559	0.640	22.185	14.664	5.928	

TABLE 5:HEAVY METAL CONCENTRATIONS FOR THREE
ST. CROIX RIVER STATIONS

0	1 STATION	2 SAMPLE DATE	3 SAMPLE TIME	4 EXT. IRON MG/L	5 EXT. MANGANESE MG/L	6 EXT. COPPER MG/L	7 EXT. LEAD MG/L	8 EXT. ALUMINIUM MG/L	9 EXT. MERCURY UG/L	10 EXT. CADMIUM MG/L
	00NB01AR0001	14-MAY-84	1630	0.16	0.03	0.002	0.002	0.120	0.02	0.001
	00NB01AR0001	25-JUN-84	1710	0.25	0.06	0.002	0.002	0.100	0.02	0.001
	00NB01AR0001	01-AUG-84	1030	0.18	0.06	0.002	0.002	0.070	0.02	0.001
	00NB01AR0001	01-AUG-84	1045	0.19	0.06	0.002	0.002	0.070	0.02	0.001
	00NB01AR0001	01-AUG-84	1100	0.18	0.06	0.002	0.002	0.060	0.02	0.001
	00NB01AR0001	23-OCT-84	1415	0.18	0.11	0.002	0.002	0.100	0.02	0.001
	00NB01AR0001	19-DEC-84	1445	0.17	0.08	0.002	0.002	0.140	0.02	0.001
	00NB01AR0001	18-FEB-85	1415	0.17	0.10	0.002	0.002	0.160	0.02	0.001
	00NB01AR0001	18-FEB-85	1416	0.17	0.11	0.002	0.002	0.170	0.02	0.001
	00NB01AR0001	18-FEB-85	1435	0.17	0.11	0.002	0.002	0.160	0.02	0.001
	00NB01AR0001	17-MAY-85	1300	0.21	0.10	0.002	0.002	0.170	0.02	0.001
	00NB01AR0013	14-MAY-84	1530	0.08	0.02	0.002	0.002	0.075	0.02	0.001
	00NB01AR0013	14-MAY-84	1535	0.08	0.02	0.002	0.002	0.070		0.001
	00NB01AR0013	14-MAY-84	1540	0.08	0.02	0.002	0.002	0.065		0.001
	00NB01AR0013	25-JUN-84	1615	0.16	0.03	0.002	0.002	0.070	0.02	0.001
	00NB01AR0013	01-AUG-84	805	0.12	0.03	0.002	0.002	0.050	0.02	0.001
	00NB01AR0013	23-OCT-84	1215	0.06	0.01	0.002	0.002	0.031	0.02	0.001
	00NB01AR0013	23-OCT-84	1245	0.07	0.01	0.002	0.002	0.018	0.02	0.001
	00NB01AR0013	23-OCT-84	1230	0.07	0.01	0.002	0.002	0.025	0.02	0.001
	00NB01AR0013	19-DEC-84	1201						0.02	
	00NB01AR0013	18-FEB-85	1230	0.09	0.01	0.002	0.002	0.035	0.02	0.001
	00NB01AR0013	17-MAY-85	1125	0.10	0.02	0.002	0.002	0.066	0.02	0.001
	00NB01AR0013	17-MAY-85	1130	0.10	0.01	0.003	0.002	0.078	0.02	0.001
	00NB01AR0013	17-MAY-85	1135	0.10	0.02	0.002	0.002	0.075	0.02	0.001
	00NB01AR0014	14-MAY-84	1710	0.59	1.80	0.006	0.006	2.500	0.02	0.002
	00NB01AR0014	25-JUN-84	1850	0.61	1.60	0.003	0.002	2.500	0.02	0.001
	00NB01AR0014	01-AUG-84	920	0.62	1.50	0.003	0.003	1.700	0.02	0.001
	00NB01AR0014	23-OCT-84	1330	0.93	2.50	0.006	0.004	2.800	0.02	0.001
	00NB01AR0014	19-DEC-84	1330						0.02	
	00NB01AR0014	19-DEC-84	1335						0.02	
	00NB01AR0014	19-DEC-84	1340						0.02	
	00NB01AR0014	18-FEB-85	1330	0.63	2.70	0.002	0.004	2.500	0.02	0.002
	BLANK	14-MAY-84	1201		0.01	0.002	0.002	0.012	0.02	0.001
	BLANK	25-JUN-84	1855		0.01	0.002	0.002	0.010	0.02	0.001
	BLANK	01-AUG-84	1201		0.01	0.002	0.002	0.010	0.02	0.002
	BLANK	23-OCT-84	1201		0.01	0.002	0.002	0.010	0.02	0.001
	BLANK	19-DEC-84	1330		0.01	0.002	0.002	0.010	0.02	0.001
	BLANK	18-FEB-85	1201		0.01	0.002	0.002	0.010	0.02	0.001

TABLE 6: NUTRIENT CONCENTRATIONS FOR THREE ST. CROIX RIVER STATIONS

0	1 STATION	2 SAMPLE DATE	3 SAMPLE TIME	4 TOTAL PHOSPHORUS MG/L	5 TOTAL NITROGEN MG/L	6 NO2 & NO3 MG/L	7 DISS. ORG. CARBON MG/L	8 HUMIC ACID MG/L
	00NB01AR0001	14-MAY-84	1630	0.019	0.16	0.05	6.2	11.0
	00NB01AR0001	25-JUN-84	1710	0.025	0.23	0.11	8.9	12.0
	00NB01AR0001	01-AUG-84	1030	0.023	0.15	0.11	7.2	11.0
	00NB01AR0001	01-AUG-84	1045	0.022	0.14	0.11	7.1	14.0
	00NB01AR0001	01-AUG-84	1100	0.023	0.13	0.11	7.3	13.0
	00NB01AR0001	23-OCT-84	1415		0.33	0.24	8.1	10.0
	00NB01AR0001	19-DEC-84	1445	0.035	0.24	0.14	9.0	15.0
	00NB01AR0001	18-FEB-85	1415	0.035	0.47	0.28	12.0	14.0
	00NB01AR0001	18-FEB-85	1416	0.035	0.44	0.26	11.0	14.0
	00NB01AR0001	18-FEB-85	1435	0.035	0.51	0.29	12.0	14.0
	00NB01AR0001	17-MAY-85	1300	0.040	0.24	0.13	7.9	
	00NB01AR0013	14-MAY-84	1530	0.025	0.12	0.02	6.0	12.0
	00NB01AR0013	14-MAY-84	1535	0.009	0.12	0.02	6.1	11.0
	00NB01AR0013	14-MAY-84	1540	0.008	0.11	0.02	5.8	12.0
	00NB01AR0013	25-JUN-84	1615	0.009	0.09	0.01	7.6	12.0
	00NB01AR0013	01-AUG-84	805	0.012	0.12	0.05	6.1	12.0
	00NB01AR0013	23-OCT-84	1215	0.006	0.10	0.01	4.5	7.0
	00NB01AR0013	23-OCT-84	1245	0.027	0.10	0.01	4.4	7.0
	00NB01AR0013	23-OCT-84	1230	0.006	0.10	0.01	4.7	7.0
	00NB01AR0013	19-DEC-84	1201	0.007	0.20	0.09	7.8	15.0
	00NB01AR0013	18-FEB-85	1230	0.012	0.20	0.07	7.3	11.0
	00NB01AR0013	17-MAY-85	1125	0.009	0.10	0.02	8.9	
	00NB01AR0013	17-MAY-85	1130	0.009	0.10	0.01	9.0	
	00NB01AR0013	17-MAY-85	1135	0.009	0.10	0.01	8.0	
	00NB01AR0014	14-MAY-84	1710		2.90	0.35	86.0	59.0
	00NB01AR0014	25-JUN-84	1850		3.00	1.30	89.0	52.0
	00NB01AR0014	01-AUG-84	920		1.90	2.10	68.0	8.6
	00NB01AR0014	23-OCT-84	1330		0.50	3.50	11.0	70.0
	00NB01AR0014	19-DEC-84	1330		5.40	0.30		56.0
	00NB01AR0014	19-DEC-84	1335		6.00	0.27	86.0	58.0
	00NB01AR0014	19-DEC-84	1340		6.00	0.17	87.0	59.0
	00NB01AR0014	18-FEB-85	1330		2.80	0.11	210.0	9.3
	BLANK	14-MAY-84	1201	0.001				
	BLANK	25-JUN-84	1855	0.025				
	BLANK	01-AUG-84	1201	0.004				
	BLANK	23-OCT-84	1201	0.005				
	BLANK	19-DEC-84	1330	0.001				
	BLANK	18-FEB-85	1201	0.001				

TABLE 7: Multiple Regression Analysis of Dissolved Oxygen Percent Saturation against Specific Conductance and Water Temperature

DO (Sat'n)	=	-.167 Sp. Cond. - 1.13 Temp + 123.6		F = 4037*
T	=	-34.5*	-35.9*	
Multiple R	= 0.89	r^2 = 0.79		n = 2209

* p = L.0001

TABLE 8: Summary Statistics for the Difference between Observed and Predicted Dissolved Oxygen Saturation

Number of Observations	128
Mean Difference	2.3
S.E. of Mean	0.21
Standard Deviation	2.4
Minimum Difference	- 3.7
Maximum Difference	5.8
Median Difference	2.7

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Figure 8 A Nomogram which Predicts Dissolved Oxygen Saturation from Specific Conductance and Water Temperature (USGS AWQM Data used to Develop Nomogram).

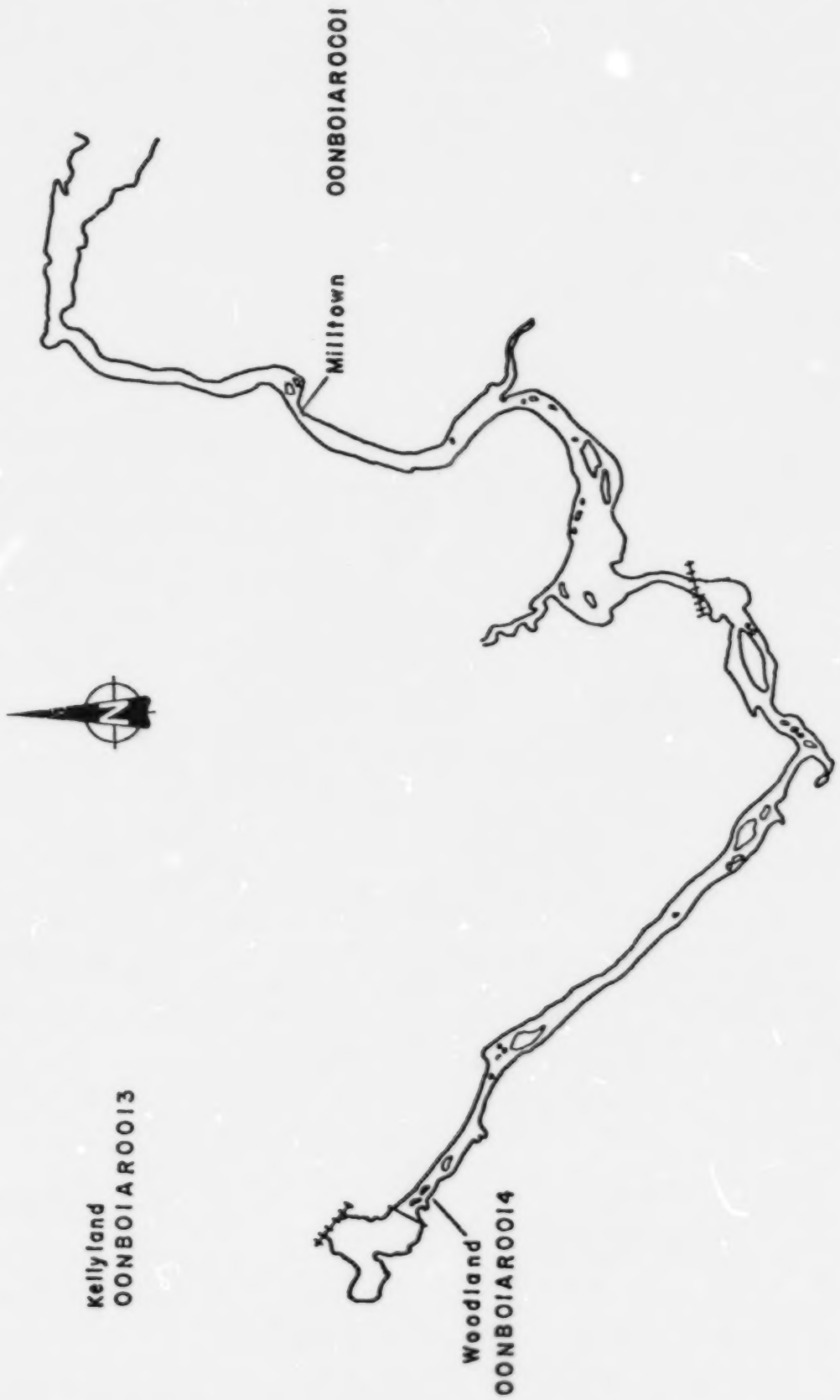

Fig. 1 Map of Study Area

FIGURE 2: MILLTOWN AMOM WATER TEMPERATURES
FROM MAY TO AUGUST , 1985

FIGURE 3: MILLTOWN AMOM PH VALUES
FROM MAY TO AUGUST , 1985

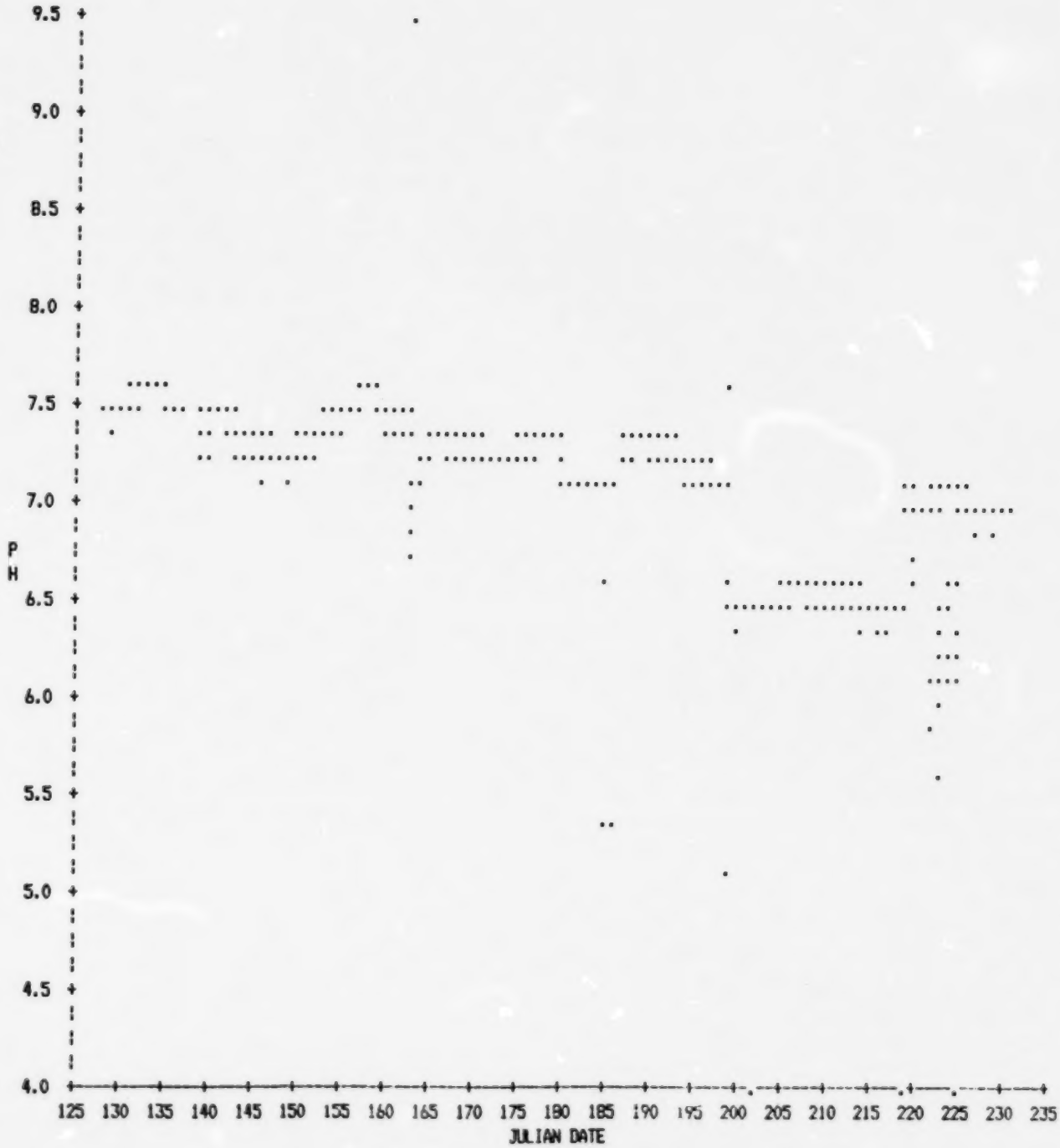

FIGURE 4: MILLTOWN AMOM DISSOLVED OXYGEN CONCENTRATION (MG/L) FROM MAY TO AUGUST , 1985.

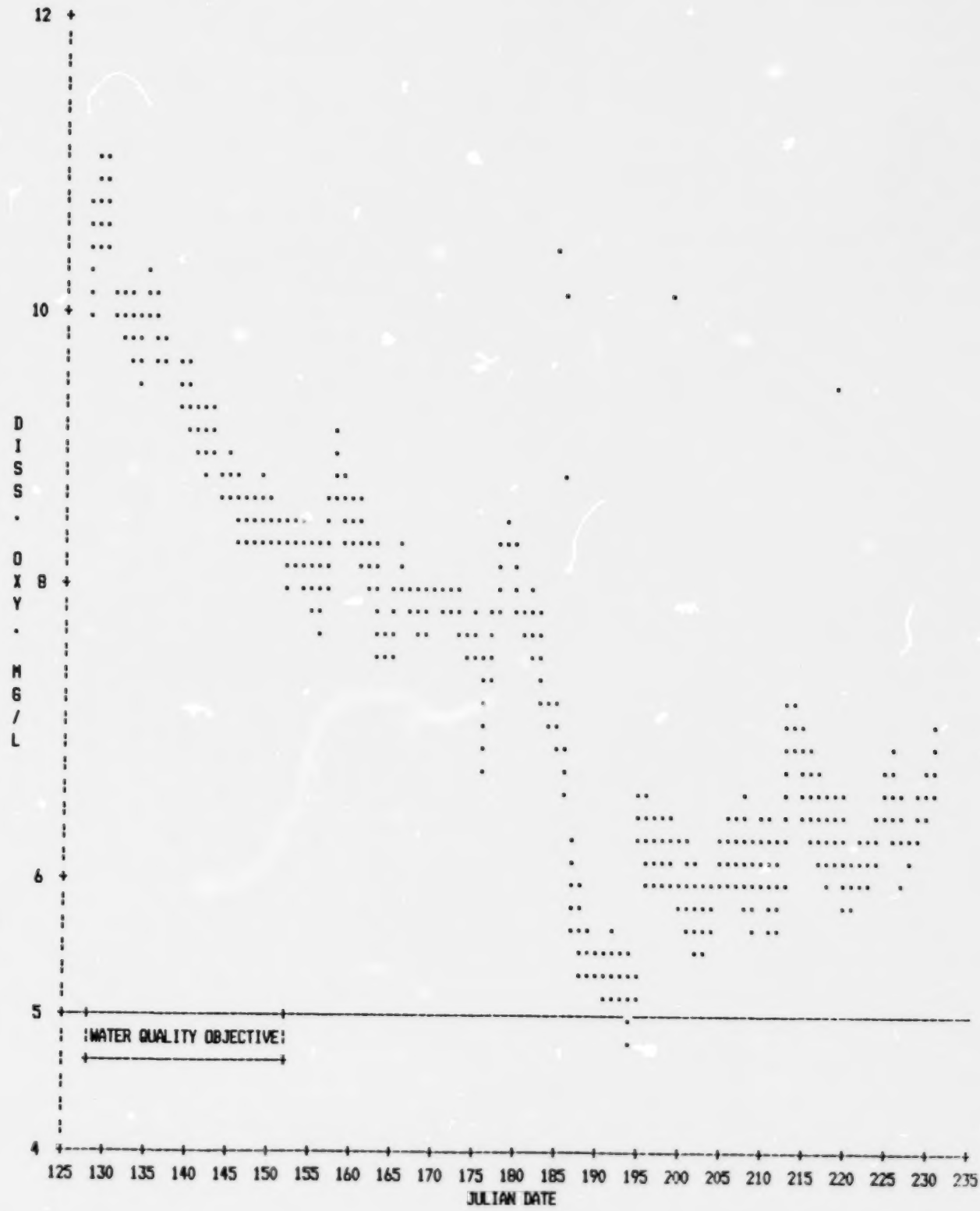

FIGURE 5:MILLTOWN ANOM DISSOLVED OXYGEN
PERCENT SATURATION FROM MAY TO AUGUST , 1985.

FIGURE 6 :MILLTOWN AWQM SPECIFIC CONDUCTANCE
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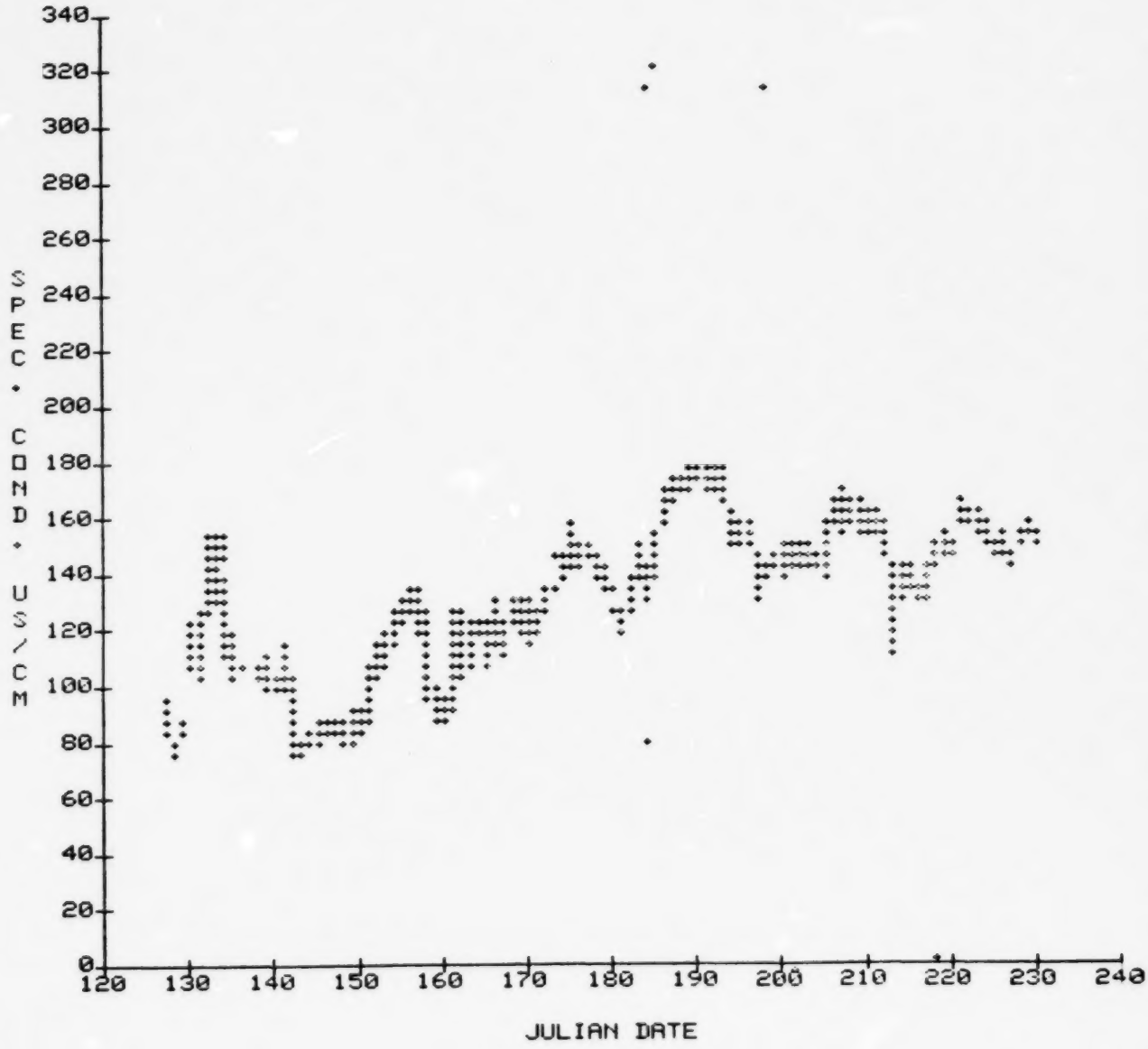

FIGURE 7 :OBSERVED VS PREDICTED
DISSOLVED OXYGEN SATURATIONS

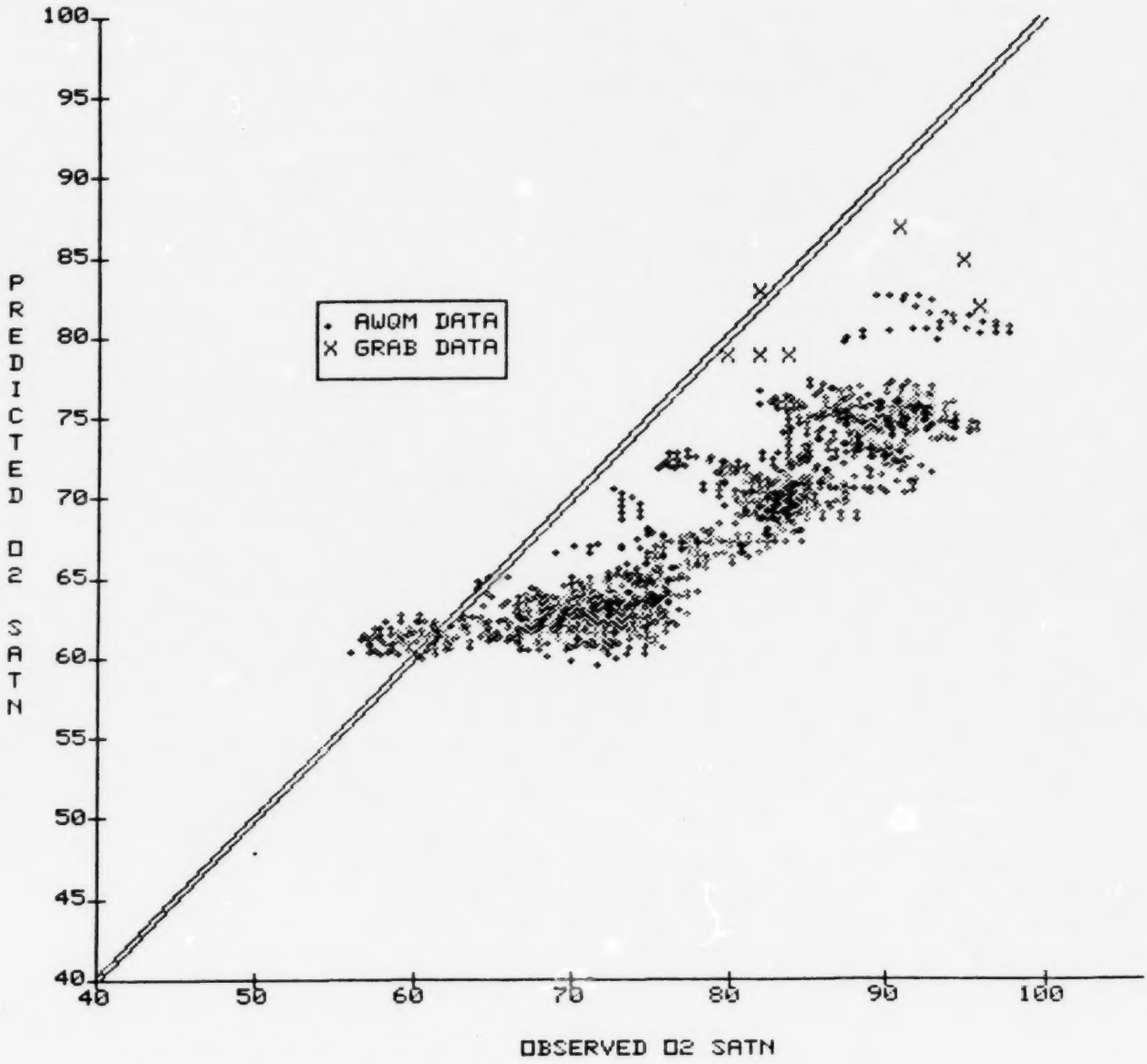

FIGURE 8 : A NOMOGRAM WHICH PREDICTS DISSOLVED OXYGEN SATURATION FROM SPECIFIC CONDUCTANCE AND WATER TEMPERATURE (USGS AWQM DATA USED TO DEVELOP NOMOGRAM :N=2209)